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# TRANSACTIONS
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# ILLUMINATING ENGINEERING SOCIETY

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# Open Space Lighting

By M. W. PEIRCE *(Fellow)* and H. F. STEPHENSON, B.Sc. (Eng.), A.M.I.E.E. *(Fellow)*

**Summary**

Most open space lighting applications have features in common and the paper collates the methods and equipment used and cites typical installations. The extent to which conventional lighting equipment can provide the light distributions needed is examined and the relative merits of low and high mounted schemes discussed. Methods of restricting glare are described. Some of the techniques employed in computing installations and in training floodlights, especially with high mounted schemes, are included.

## (1) Introduction

The lighting of outdoor open spaces for industry, transport and sports covers many aspects of illuminating engineering. Installations may range from a few low-mounted general dispersive units lighting a small factory yard to one of several hundred kilowatts split between a number of tall towers each carrying many high wattage, carefully trained and focused projectors.

One feature common to all open space lighting is that the contrast between the light source and its background is almost certain to be excessive when compared with ordinary standards of interior lighting. The background luminance is not under the control of the lighting engineer, and all he can do to limit the luminance range within the field of view is to control the intensity distribution and cut-off angle, limit the maximum source luminance or choose positions for the light sources which keep them away from the line of sight. Special optical designs are often used to produce asymmetric light distributions which restrict glare and give a required uniformity of illumination. It is frequently necessary, in a particular case, to choose between a system using a large number of low-mounted fittings and a system of floodlighting from high towers with a small number of powerful projectors. Often the latter method produces the more effective and neater looking installation, but towers are expensive. An analysis of the relative costs of fittings and cabling may offset the expense of towers; this factor, together with local circumstances, may dictate the choice of method.

Outdoor lighting, especially where the units themselves are relatively inaccessible, raises problems of mechanical design to ensure that the equipment will withstand weathering, resist corrosion and permit easy maintenance.

## (2) Light Distributions for Space Lighting: Theory and Practice

### (2.1) The Problem

In designing fittings for space lighting, the familiar criterion of uniform illumination on a horizontal surface is not necessarily the ideal. Usually the appearance of a lighted area depends not only on the illumination and the reflection characteristics of the surface, but also on the viewing conditions. All manner of surfaces may be encountered, ranging from those with high to low reflection factors and with near diffuse to preferential reflection, of which grass is perhaps the most difficult to light satisfactorily. Again, in lighting outdoor constructional projects, for example, vertical surfaces may be of primary importance, whereas in sports lighting not only is the horizontal playing area to be well lighted, but also vertical surfaces on the players and

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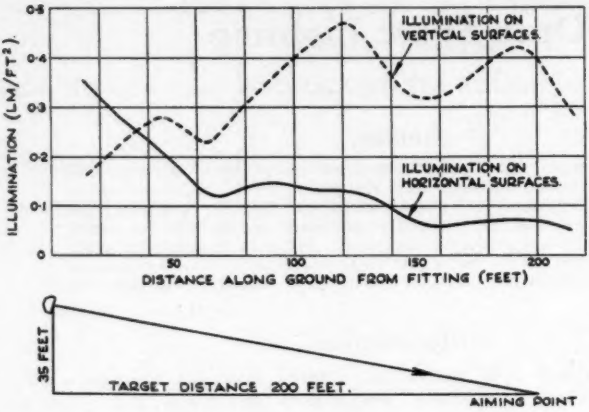



*Fig. 1. Illumination distribution from modified trough parabolic floodlight, equipped with two 400-watt H.P.M.V. lamps.*

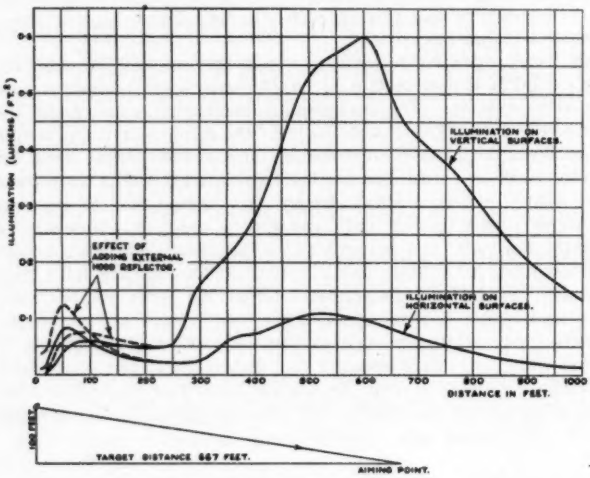



*Fig. 2. Illumination distribution from floodlight with paraboloidal mirror equipped with 1,000-watt lamp. (Floodlight similar to that shown in Fig. 6.)*

objects in the air such as a football. Apart from specialised applications where the problem can be precisely defined, there is no hard and fast rule.

Experience has shown that quite wide diversities, perhaps 5 : 1, are acceptable provided the changes in illumination are smooth; similarly the ratio between illumination on a horizontal and vertical surface at any point may vary quite considerably provided it does not change rapidly. For example, Fig. 1 shows an illumination distribution which gives excellent results, but Fig. 2, in which the diversities are greater, is often found to be acceptable in practice. Much will depend, of course, on how the considerations mentioned above affect a particular job.

In examining Figs. 1 and 2 it should be remembered that the horizontal distance scale is cramped and the illumination scale extended, so that variations are exaggerated. A compromise can usually be found for uniformity of illumination on vertical and horizontal surfaces, and an acceptable visual appearance is produced if glare is

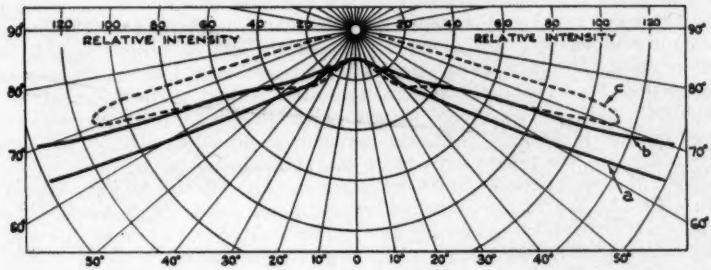



*Fig. 3. Light distribution curve: a: Intensity proportional to $\sec^3\theta$ giving constant illumination on horizontal surface. b: Intensity distribution to give, at mid-span, half the illumination on horizontal surfaces beneath fitting. c: Intensity distribution from symmetric specular fitting with 500-watt lamp.*

restricted. Appropriate siting of units can help materially in obtaining the best appearance.

The theoretical light distribution needed to provide a given diversity of illumination over an area may be calculated by well-known point-to-point methods for either a single fitting or as a component in the build-up from several fittings.

To take simple examples, Fig. 3 shows the distribution for a single unit giving constant illumination on the horizontal (luminous intensity proportional to $\sec^3\theta$) and also that for a unit giving at mid-span half the illumination beneath the fittings.

In practice, distributions of this type, from a symmetric unit with a G.L.S. lamp, may be achieved for spacings only up to about 2½ times the mounting height by using a critically focused specular reflector. This is due partly to the difficulty of re-directing sufficient light at the higher angles and partly because, to avoid glare, there must be a cut-off angle with rapidly reduced intensities just beyond the peak. An actual distribution of this type is shown dotted in Fig. 3.

### (2.2) Low Mounting Units

Often, however, a considerable diversity can be tolerated, and for low mounting heights use is made of less critical and cheaper reflectors, such as vitreous enamelled steel or plastic. These may be either symmetric as in the well-known dispersive type or asymmetric like the industrial angle unit. For such diffusing reflectors the reflected light distribution is substantially a circle which, added to the bare lamp distribution and modified by the cut-off, gives the final light distribution. Where an asymmetric unit is required, the widespread distribution from vitreous enamel is often combined with a directional component from an additional specular reflector. Distribution curves for such reflectors are shown in Fig. 4 and may be compared with those in Fig. 3.

The many space lighting applications of tubular fluorescent, sodium and H.P.M.V.

*Fig. 4. Intensity distribution from typical fittings equipped with 1,000-watt lamps. a: Vitreous enamelled dispersive reflector. b: Vitreous enamelled industrial angle reflector. c: Vitreous enamelled angle reflector with additional specular reflector.*

lamps both plain and colour-modified are for the most part at low mounting heights and short throws. In general the low source luminance and large source size, especially with colour-modified H.P.M.V. lamps, preclude the use of critical optical systems, at least in fittings of practicable size. They are generally used in vitreous enamel, specular reflectors or in enclosed semi-decorative fittings. The 1 kw. M.B. lamp, however, has a fairly high source luminance and has been used successfully in an asymmetric area floodlight containing specular anodised aluminium reflectors for medium ranges, and in groups even up to 100 ft. mounting height.

In lighting moderate sized areas the larger wattage reflector spotlight type of lamp may be used. Lamps of 500 watts are available and need only a simple housing to give protection from rain. The light distribution is fixed by the lamp maker and can only be modified by adding a front glass to give more spread.

Although lamp replacements are expensive the initial cost may be low, and if the burning hours are short, as with practice areas on sports fields, the scheme may be economic. This solution can be useful where strong enough supports for floodlights are not available.

**(2.3) High Mounting Units**

With longer throws and higher mounting heights, the greater intensity needed at the high angles is obtained with specular reflectors giving a more concentrated distribution, but covering only a restricted angle in azimuth. Paraboloids may be designed so that when used with different forms of filament and different degrees of diffusion on the specular reflector surface, a wide range of beam divergences can be obtained from one basic unit as indicated in Fig. 5. Additional spread, usually only required in one plane, may be obtained with fluted or prismatic front glasses at the

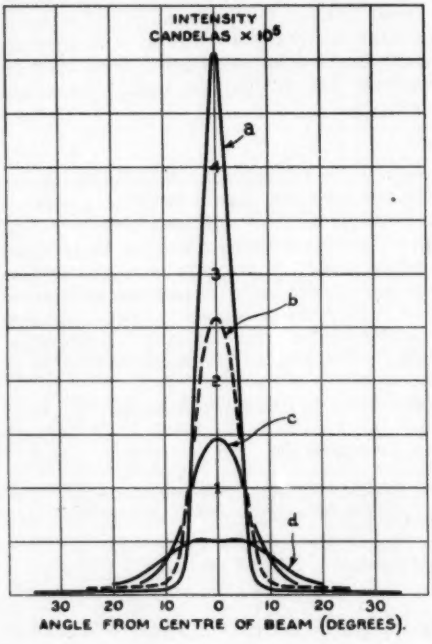



*Fig. 5. Intensity distributions from 1,500-watt floodlights with paraboloidal mirrors.*
*a: Smooth specular reflector, Class B2 lamp.*
*b: Diffused specular reflector, Class B2 lamp.*
*c: Diffused specular reflector, G.L.S. lamp, focused.*
*d: Diffused specular reflector, G.L.S. lamp, de-focused.*

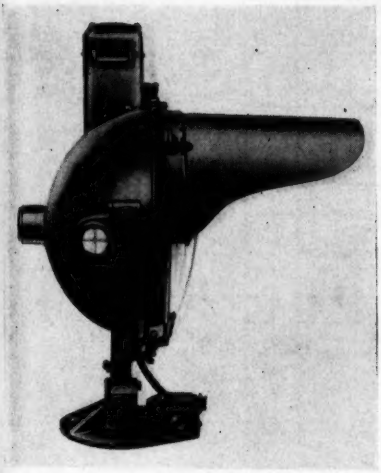


*Fig. 6 (left). Heavy duty floodlight with external hood reflector. When the lamp is in focus an image of the filament produced by a "pinhole" is formed on the ground glass screen on the side. A second screen is to be found at the back of the unit.*
*Fig. 7 (right). Light-weight apron floodlight showing prismatic front glass.*

expense of some peak intensity. Larger amounts of spread require reflectors of sectional, para-elliptical or para-barrel form.

The light distribution from fittings with paraboloidal reflectors, using G.L.S. or Class B filament lamps, is nearly symmetrical above and below the beam centre. Some of the light above the beam centre is responsible for glare and much is often wasted in the air, especially with very long throws, although it may be utilised effectively in several types of sports lighting. An external hood reflector can be fitted to re-direct some of the light on to the area beneath the fitting as shown in Fig. 6, and many other devices have been used to obtain a rapid run back above the beam centre. Louvres need to be very closely spaced to obtain even a five deg. cut-off, they are inefficient, appreciably reduce the peak intensity and are expensive to make. Cut-off screens or spill rings are often used for example in railway yard lighting to prevent direct glare from reaching an adjacent main line track. Another method is to use a split paraboloid, the focus of the upper half being at the back of the lamp filament and that of the lower half at the front of the filament. In this way light from other points on the filament is reflected below the peak direction from both halves of the mirror. The device is effective but expensive and critical.

A typical curve showing the variation of the illumination on horizontal and vertical surfaces for a fitting with a paraboloidal reflector is given in Fig. 2. It will be seen that the maximum illumination occurs not at the aiming point, but a little towards the tower carrying the floodlight. The illumination falls off to both sides of this point and then rises close to the base of the tower due to the bare lamp contribution, the shorter throw and the rapidly decreasing angle of incidence. The effect of adding an external hood reflector is also indicated.

Where the throw is not so long as to need a very high peak intensity, a prismatic front lens may be used to fill in the dip in the illumination distribution, and also to obtain a more rapid run back above the peak. An interesting example is the fitting shown in Fig. 7 used for airfield apron lighting. This consists of a deep paraboloid

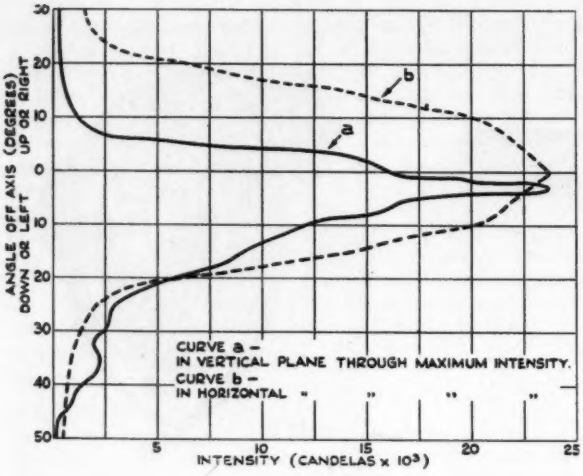



*Fig. 8. Intensity distribution curves for floodlight of Fig. 7.*

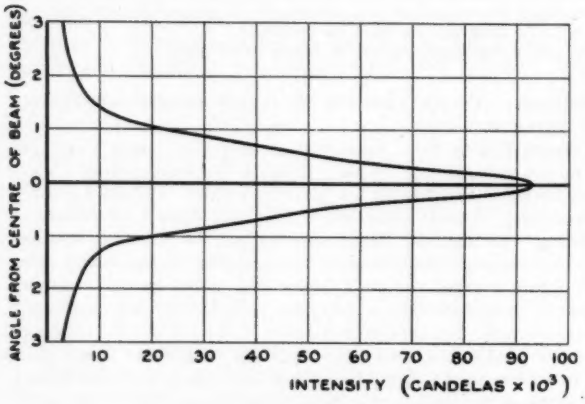



*Fig. 9. Intensity distribution curve in vertical plane of symmetry for long range trough parabolic floodlight equipped with 1 kw. "Horizon" lamp. Comparison with Fig. 5 emphasises the extremely small vertical divergence.*

with the lamp mounted along the axis, thus giving a large collection angle from the filament. Horizontal prisms on the front glass re-direct downwards some light from the main beam and vertical flutes give the required sideways spread. An external hood reflector is also fitted. The beam distribution is shown in Fig. 8, and clearly indicates the degree of asymmetry obtained in the vertical plane.

On the Continent the "Infranor" projector is used extensively for all forms of space lighting and has been well described in the literature[1, 2]. Basically it comprises a number of pre-set mirror segments of cylindro-parabolic or elliptical form usually arranged to give a rectangular beam shape. Part silvered low voltage filament lamps of up to 5 kw. are used and because of the small filament and large size of the unit, small divergences are possible. The overall efficiency is said to be high[1]. A 3 kw. floodlight weighs nearly 3 cwts., it is 4 ft. 7 in. high, 4 ft. wide and with spill shield 3 ft. deep.

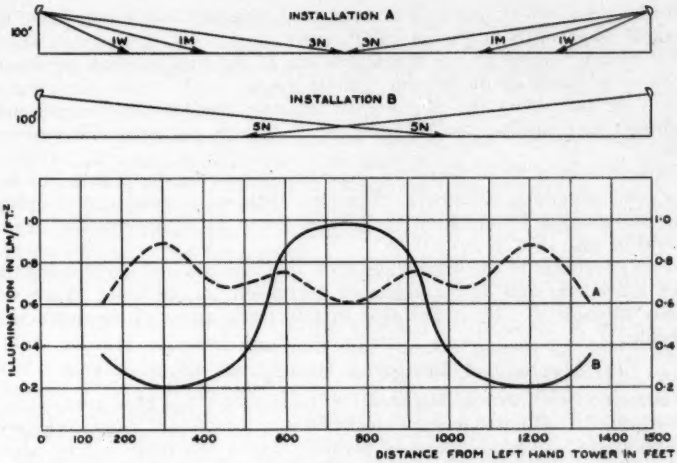



*Fig. 10. Two methods of training floodlights and resulting illumination distribution on a horizontal surface.*
*N—Narrow beam floodlight. (Beam angle 12 deg.)*
*M—Medium beam floodlight. (Beam angle 16 deg.)*
*W—Wide beam floodlight. (Beam angle 26 deg.)*

### (2.4) The Use of Linear Light Sources

Where precise light control in the vertical plane is required, together with a wide sideways divergence, the linear source used in a trough reflector offers many advantages. Suitable light sources are the horizon type filament lamp or the horizontal burning H.P.M.V. lamp. Because of the narrow source width, a small vertical divergence can be obtained so that above the beam centre a rapid run back is possible, and if a shield is necessary to restrict glare, it need only be of small dimensions. Of the two sources, the filament lamp with its much higher luminance is generally used for the longer throws, say 500 ft. to 1,000 ft., because of the high intensities needed. Either source is suitable at shorter throws unless colour is important. Fig. 9 shows the intensity distribution of a long range trough parabolic fitting using a prefocus 1-kw. horizon type filament lamp.

For the shorter throws, say up to 300 ft., the beam shape below the beam centre can be arranged to fill in the dip in the illumination distribution, either by a suitable reflector contour[3] or by modifying a trough parabolic fittings. One successful design uses the lamp set slightly away from the true focus, producing a split beam. Each half is then modified by prismatic and diffusing front glasses so that a rapid run back is obtained above the beam centre, a slow run back below it and the two components merge smoothly into each other just below the peak. The illumination distributions from typical units of the latter type are shown in Fig. 1.

### (2.5) Methods of Training High Mounted Floodlights

If we consider two banks of floodlights 100 ft. high and spaced say 1,500 ft. apart and trained towards one another, a choice may be made between two systems of training (see Fig. 10).

In the first system three floodlights out of every five have narrow beams (12 deg.) and are trained to the centre line of the area; one has a medium beam (16 deg.) and

is trained to a point 420 ft. away. The remaining floodlight has a wide beam (26 deg.) and is trained downwards to a point 230 ft. away.

In the second system all the floodlights are of the narrow beam type, and they are all trained to points on the ground 1,000 ft. away.

As will be seen from the illumination diagram the first system provides more even lighting; nevertheless, the diversity of 5:1 with the second system may be acceptable.

The first system is to be preferred, especially when the floodlights can be set up with care and maintained accurately. Since the angle of depression of the floodlights is greater, the average illumination may be expected to be greater and the amount of glare will be less.

The one advantage of the second system is its simplicity—all the floodlight mirrors and lamps are similar and all the angles of depression are the same. Such simplicity is especially valuable if there is any fear that focusing and training instructions may be disregarded.

### (3) Mechanical Design of Fittings for Outdoor Use

The construction of fittings intended for use outdoors has been adequately treated in the literature(4). Maintenance of such fittings, which are often inaccessible, is difficult and costly, so good design is needed. Much attention is now paid to the proper choice of materials with good inherent corrosion resistance for making fitting bodies. Auxiliary parts such as bolts, hinge pins, toggle clips, etc., still present problems, and as yet no satisfactory substitute has been found for stainless steel. Cheaper alternatives such as mild steel treated with one or other of the many plating processes have only a limited life. For some applications the recent techniques of spraying nylon, polyethylene and P.V.C. offer the possibility of providing a fairly cheap corrosion

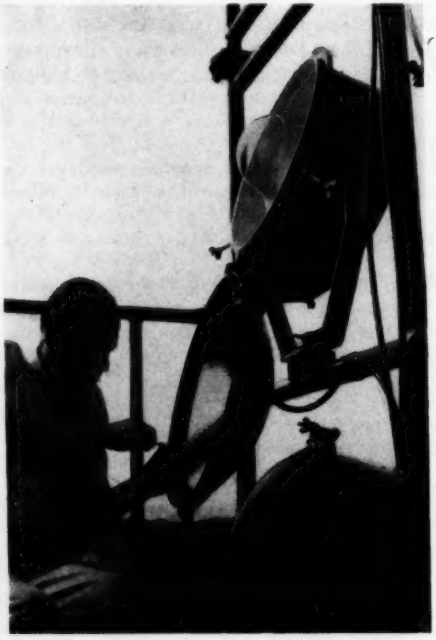


*Fig. 11. Lighting tower at Wembley Stadium showing floodlights with hinged backs and convenient access to them.*

resisting finish on steel or light alloy castings. The process is as yet too new for much field experience to be available. So far, suitable plastic materials with sufficient thermal resistance and mechanical strength for the large wattage fitting are not available at reasonable cost. Fibre reinforced plastic materials may become more widely used when bonding resins which will withstand higher temperatures become available.

Materials for specular reflectors include silvered glass, anodised aluminium and plated metals. Of these, glass mirrors with suitable protection over the silvering are known to have a long service life. Metal mirrors, although popular because of freedom from accidental breakage, are less satisfactory. Plating has only a limited life in outdoor conditions and anodised aluminium, even of high purity, is liable to fail rapidly unless well protected from damp.

Easy lamp replacement is essential, and where fittings are mounted on poles or towers a hinged back provides convenient and safe access to the inside of a unit. Fittings of this type are shown on a tower in Fig. 11. Incidentally, the tower design should allow of easy access to the units and for this pattern of fitting should not obstruct the opening of the hinged back. With long range floodlights, where the optical system is critically focused, the use of pre-focus capped lamps has much to commend it. As an alternative the fitting shown in Fig. 6 is provided with ground glass screens on the side and back. Pin-hole images of the filament are formed on them so that the fittings may be re-lamped and focused in daylight.

It is possible to design and construct fittings which will remain in serviceable condition for a very long time without any attention, but the cost of such designs would normally be considered excessive. The cost can be greatly reduced if it can be accepted by the customer that durability is dependent to a large extent on periodic maintenance.

## (4) Applications

There is no simple set of rules by which to determine whether a given installation shall be lit by high or low mounting. In some places the physical conditions will impose a decision as, for example, in lighting for dam construction where closely spaced short poles cannot be installed. In general, however, either method is possible, and the best guide is to consider examples of what has been achieved in practice.

At low mounting heights any of the available light sources may be used and the choice is only limited where colour is important. At high mountings a compact and bright light source is needed, and in practice this almost always means a tungsten filament lamp except in a few instances where the quartz type H.P.M.V. lamp can be used.

The effectiveness of area lighting installations under all sorts of weather conditions is important and in general there does not seem to be much to choose between low and high mounting. Fogs in day-time cause less traffic chaos than similar fogs at night, so that lighting can be expected to improve fog conditions which would otherwise hold up work or at sports stadia cause a meeting to be abandoned. Experience shows that in light mists an installation is improved, more so with high mounting because the light is better diffused over the area. It has also been said that due to the brightness of the mist there is a light background giving improved visibility of objects. Where the mist is combined with dirt particles some light is absorbed and installations at lower mounting heights are less affected. In really dense fogs neither scheme will allow work to continue.

### (4.1) Lighting of Railway Sidings [5,6]

There are at least three types of railway yard which need to be considered separately, quite apart from purely local problems which may arise in a particular instance: (a) Goods marshalling yards, where goods trains are made up for dispatch

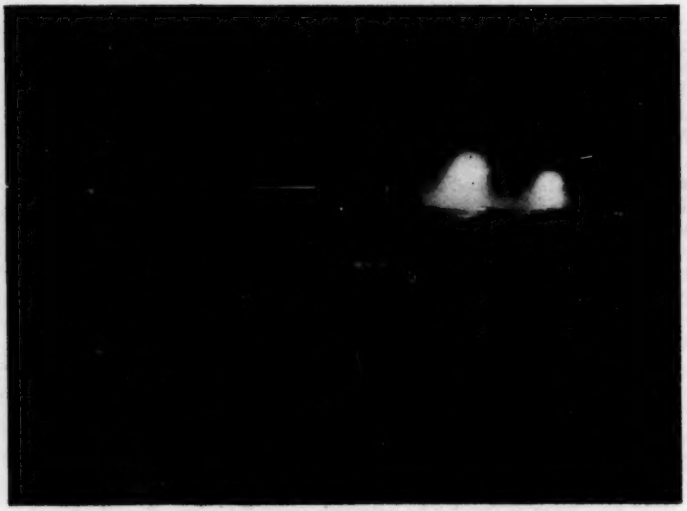


*Fig. 12. Coal siding at Stella Power Station lit from four towers 100ft. high.*

to different areas. (b) Coal yards and the like, where complete goods trains are either filled or emptied and handled more as complete trains than as separate wagons. (c) Passenger yards, where passenger coaches are stored, serviced, cleaned and made up into trains for a nearby passenger terminus.

The lighting requirements for the second group are for a general light over the main area of the siding, a good light near points and probably a specially lighted area where the trucks are filled and emptied. There should be a minimum of obstruction between the roads and a system of floodlighting is likely to provide a satisfactory solution. Groups of floodlights on high towers are sited near the areas of the points where stray light will give good illumination from almost directly overhead. The towers may be a quarter of a mile or more apart and still provide reasonable seeing conditions in the main area of the yard.

At the Stella Power Stations near Newcastle, Fig. 12, there are two coal sidings, one for each station. Each siding has four 100-ft.-high towers, each carrying an average of 24 floodlights. The approximate distance between opposing towers is 1,500 ft. and the illuminations obtained on the horizontal range from about 3 lm/ft$^2$ in the region of track intersections to about $\frac{1}{2}$ lm/ft$^2$ at mid-span. The corresponding illuminations on planes normal to the floodlights were about 6 lm/ft$^2$ down to about 1 lm/ft$^2$. The total loadings on the installations were about 100 kw. for each siding.

The first group needs similar lighting for the points areas but a higher class of illumination in quality and quantity is wanted in the marshalling area for the shunters making up the trains. Here destination labels must be read and shunting operations performed. If the yard is full there may be troublesome shadows cast from one road to another. The tendency is to need a larger number of positions for the light sources, but since it is still desirable to keep obstructions between the roads to a minimum it is necessary to arrive at a suitable compromise. At Hither Green the problem is solved by using 150-ft. towers.

The third group may need better lighting than the other two, and here it seems necessary to provide a light source between each road because they are spaced only at about 11 ft. 6 in. centres and one coach would completely shadow the next one.

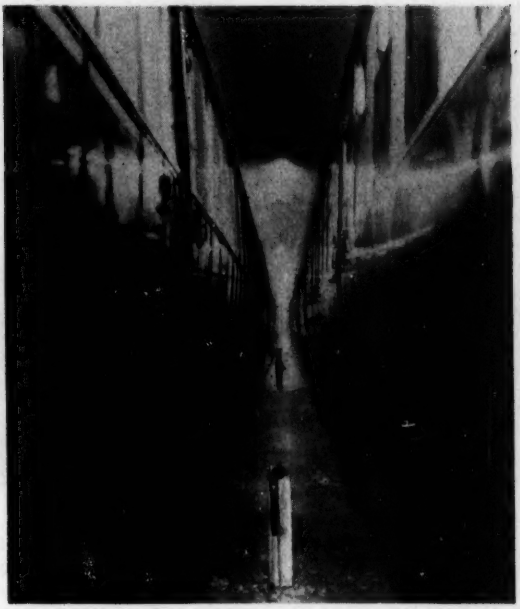


*Fig. 13. Carriage siding at Willesden lit by 200-watt fittings. Excellent lighting is provided in the narrow gap between coaches.*

The night work includes servicing the coaches with supplies of water and gas, connecting up steam for pre-heating and an electrical supply for boosting batteries.

In the Willesden installation (Fig. 13) there are 23 roads in all and gantries have been provided carrying 200-watt directional units spaced one between each road. The fittings are mounted at 25 ft. above the ground and the 11 gantries are spaced 180 ft. apart. 2,000-3,000 coaches are serviced at Willesden every week. The lights are switched in four groups by means of a ripple control system.

In the three types of railway yard considered, the amount of glare permissible is not necessarily the same in each, but it is, of course, kept to the minimum possible with the type of lighting chosen. Floodlighting installations of comparatively low mounting height tend to be cheaper but more glaring than those using a large number of smaller sources. Glare is reduced in floodlighting schemes as the height of the supporting structures is raised, but this increases the cost. The most economical scheme which will provide satisfactory working conditions can only be decided after a quite careful study of the operations carried out at the particular yard being considered.

An advantage of floodlighting, which is sometimes of considerable importance, is that the obstruction caused by lamp columns between the roads can be avoided. Where shunters are dealing with moving wagons, the existence of these obstructions in the narrow space between roads can be a serious danger.

A floodlighting installation must not dazzle drivers of trains using the main lines, which in many instances run close to sidings; nor must floodlights be placed so that they detract from the effectiveness of signal lights. If the towers are sited so that the floodlights are trained at an angle away from, rather than towards, the main line, and if they are accurately focused and directed, the difficulty should not arise, but it is sometimes necessary to fit the floodlights with concentric louvre systems or simple shields to control the spilled light.

The level of illumination usually provided is between 0.5 and 1.0 lm/ft$^2$ average,

*Fig. 14. Installation of dock lighting at Tilbury, 1930.*

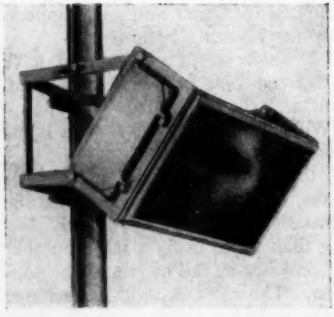


*Fig. 15a. (above). Lantern for lighting quaysides equipped with two 400-watt H.P.M.V. lamps. This can be mounted up to 100 ft. back from the water's edge.*

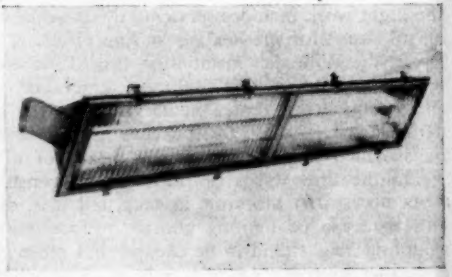


*Fig. 15b. (top right). Wall mounting lantern for quaysides and loading bays equipped with two 5-ft. 80-watt MCF/U lamps.*

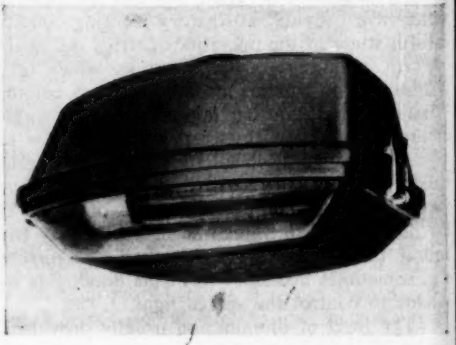


*Fig. 15c. (right). Cut-off reflector type enclosed lantern for dock areas used with either 250- or 400-watt mercury lamps. It has a controlled cut-off at 70 deg.*

and this is normally sufficient for any of the three types of sidings which have been discussed. The diversity of illumination should be less in marshalling yards than in coal sidings. Whatever system of calculation is used, it is useful to check the average illumination by a simple lumen calculation based on the beam lumens of the lighting unit used and the average area per unit. Although some small proportion of the beam lumens may not reach the target area, there is also in a floodlighting scheme some light outside the main beam which will reach the area and which can be expected to more than compensate for any such loss. An average narrow beam floodlight, using a 1,000-watt lamp of 17,800 lumens has a beam of about 6,500 lumens and total light output of 14,250; it is suggested that the figure of 6,500, divided by the area per floodlight be used as a rough guide to the average illumination and as a check to any other method of calculation used.

**(4.2) Dock Lighting** [7]

In dock areas, it is required to provide lighting which will permit safe movement on the quays and which will not hinder the handling of ships or interfere with vision of navigation lights set up for their guidance. Fig. 14 shows an installation of cut-off lanterns at Tilbury dating from about 1930 and using mirror glass reflectors with a cross-over distribution, a peak angle of 65 deg. and a cut-off angle of 70 deg. A spacing height ratio of about 2½ : 1 can be used and the reflector, with its high efficiency approaching 80 per cent. in the lower hemisphere, is still used to-day.

Where it is essential that the quay should have an unobstructed passage for a mobile crane or the like, it is sometimes necessary to place the lighting fittings 100 to 150 ft. back from the water's edge and a special unit using two 400-watt mercury vapour lamps and an aluminium parabolic reflector has been produced for this purpose (Fig. 15(a)). The unit can be mounted at 35 to 70 ft. above the quay level and provides 2 to 3 $1m/ft^2$ at the quay edge. The higher mounting is preferable, particularly if it is desired not to spill the light beyond the edge of the quay. Fig. 16 shows the lighting at Devonport Dockyard using the mercury lamp fitting at a mounting height of 35 ft. on lattice steel towers.

*Fig. 16. Lighting at H.M. Dockyard, Devonport, using fitting shown in Fig. 15a.*

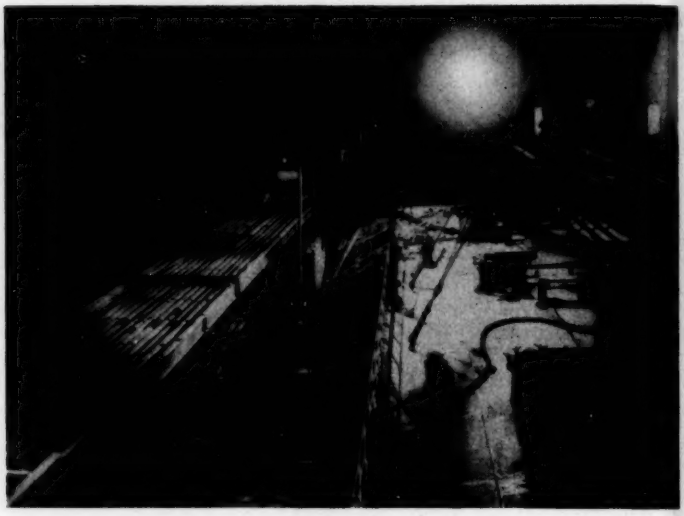


*Fig. 17. Oil jetty lighting. The confusion of pipes, valves and other obstructions is clearly seen.*

Another wall mounting lantern for use where the throw required is not so great is equipped with two 5-ft. fluorescent lamps (Fig. 15(b)).

Cut-off reflector lanterns with horizontal 250-watt or 400-watt mercury lamps (Fig. 15(c)) are widely used for lighting dock areas where it is desirable to eliminate glare for navigational purposes or for any other reason.

**(4·3) Oil Jetties**

Oil jetties such as that illustrated in Fig. 17 have similar problems to other dock and harbour lighting with the added hazard of the inflammable material. The number of pipes and valves both on the ships and on the jetties must be seen to be believed and it is not an easy task to pick a way in safety amongst them. Flameproof fittings with 5-ft. 80-watt MCF/U lamps and 200/300-watt filament lamps in cut-off reflectors are used, but 500-watt and 1,000-watt flameproof floodlights are useful where it is essential to project a beam of light from a distance[8].

**(4·4) Sports [9]**

(4.4.1.) *Football lighting*

Football floodlighting[10] has now developed to a stage where league matches are frequently commenced in daylight and completed under floodlighting. This, in itself, presents a problem because the effect of switching on the lights in a half light is not very dramatic, and some clubs previously quite satisfied with an installation of, say, 90/100 kw. are increasing this load. By the time the next football season opens there will be at least eleven grounds with installations of approximately 200 kw. and four with over 300 kw.

A year or so ago we were reading with some astonishment of American grounds with over 1,000 kw. Considering that these are baseball grounds with a much larger playing area than our football grounds, we can claim that our own installations are beginning to be comparable.

The increasing tendency to over-run the lamps by about 10 per cent. needs some comment. Since the hours of use per year of these installations is extremely small, it

is economically sound to obtain from each floodlight about 35 per cent. more light from an increase of about 15 per cent. in watts, even though it is estimated that the lamp life is reduced to about 300 hours. This life represents several years' use but some method of warming up the lamps is necessary so that they are not switched directly on to the higher voltage. The introduction of a suitable resistance, which is subsequently shorted out of circuit, is a satisfactory method.

(4.4.2) *Athletics*

It is beginning to be appreciated that if this country is to achieve a leading place in athletics against international competition then really adequate training facilities must be provided, including running tracks which can be illuminated at night. There is at least one track in the London area where training of a sort is carried on after dark with the aid of oil hurricane lamps placed on the ground as markers round the inside of the running track : such lighting does little to encourage athletes. However, an installation at Tooting Bec (Fig. 18) does provide reasonable facilities and the cost to the athletes is sixpence each for the use of the track and dressing-rooms.

This installation consists of 48 fittings of the type used for greyhound and speedway tracks[9], but mounted at 16 ft. above the ground on bent tubular poles at a spacing of about 25 ft. The intensity required is not so high as for a greyhound track since the lighting is not provided primarily for spectators. The fittings have 750-watt lamps along the straights and 1,000-watt lamps on the bends. The amount of light provided here is perhaps rather above the absolute minimum.

(4.4.3) *Small area sports lighting*

For lighting small outdoor areas the vitreous enamelled industrial angle reflector is extremely useful, cheap and serviceable. It is suitable for school playgrounds, public park playing areas, bowling greens, miniature golf courses, and has been accepted by the Lawn Tennis Association as the most appropriate type of unit for lighting lawn tennis courts. The Lawn Tennis Association has published detailed recommendations in its official journal[11], and it is hoped that this will lead to a very desirable uniformity in layout and mounting height.

Although small areas in parks may be lighted by reflectors as described above,

*Fig. 18. Running track at Tooting Bec.*

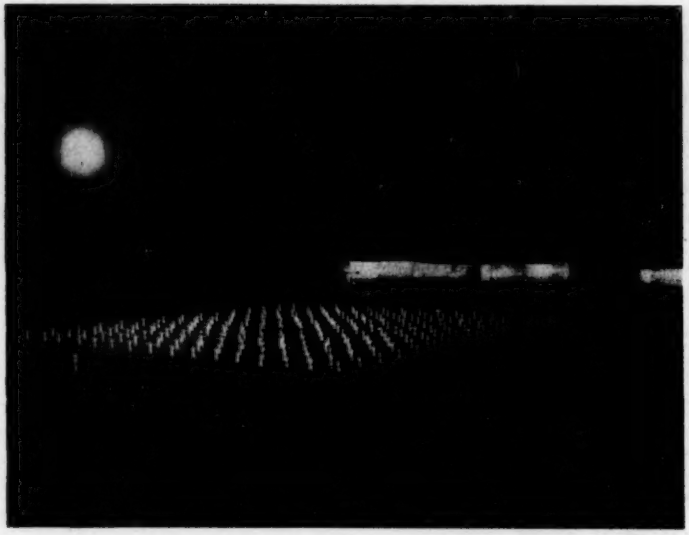


*Fig. 19. Display area lighting. Northern Command Tattoo 1954.*

decorative lanterns are, of course, frequently used and have been described elsewhere[12].

**(4.5) Large Display Areas**

Lighting for open-air displays or tattoos will frequently follow the principles of football floodlighting with the difference that the spectators do not usually occupy all sides of the display arena and the performers, like actors on a stage, expect and even welcome the glare of the lights. Military searchlights have been used, notably

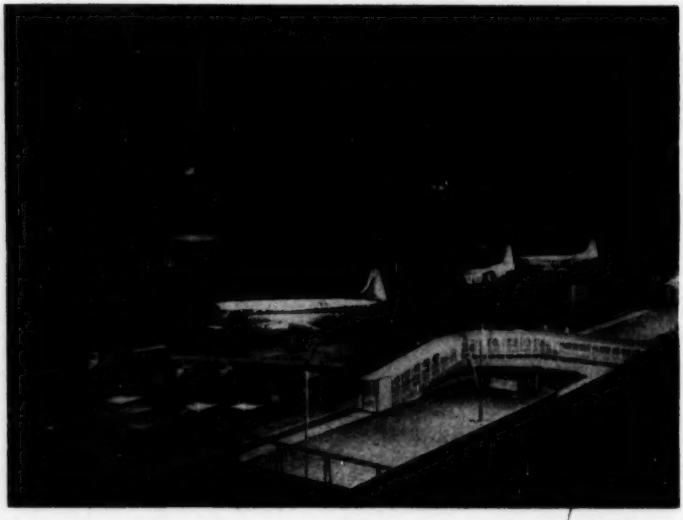


*Fig. 20. Apron lighting at London Airport showing taxi track between lighted areas.*

at the pre-war Aldershot Tattoos, and produced some memorable spectacles. Fig. 19 shows a display at the Northern Command Tattoo at Roundhay Park, Leeds, in 1954. The park forms a natural amphitheatre, and the lighting was from three temporary tubular scaffolding towers each carrying a total of 24 floodlights with 1,500-watt lamps. An average illumination of 10 lm/ft$^2$ was obtained.

**(4.6) Areas Used by Aircraft**

The aprons of an airport provide an interesting application of area lighting. The runways on which an aircraft lands are indicated by marker lights: other guide lights are switched on to lead each incoming aircraft to the position on the apron which it is to occupy. It is important that any apron lighting should not make it difficult for the pilot to see the guide lights, and this requires units having a rapid run back above the peak together with a wide sideways distribution. Suitable optical systems have been described in Sections (2.3) and (2.4), and an illumination distribution from a unit equipped with a linear source is given in Fig. 1.

The illustration of apron lighting at London Airport (Fig. 20), shows clearly the cut-off which allows the line of taxi-track lights to stand out between the two illuminated areas. The unit used for this installation is shown in Fig. 7 and its light distribution in Fig. 8.

**(4.7) Vehicle Parks and Depots**

Vehicle parks may be large or small, temporary or permanent. They may need lighting of a utility nature or be in a position where decorative treatment is required. The vehicles may be entering and leaving in ones and twos or there may be a mass movement at particular times. In some instances, particularly bus depots, the problem is similar to that of a railway siding in that tall vehicles are parked side by side and it is difficult to light between them. A few units mounted on a tower or adjacent tall building form a neat solution if the light can be directed between the vehicles; it is often necessary, however, to use a large number of suitably positioned low-mounted units. In car parks the problem is easier, and it can be said that the fewer columns there are the better it is, since they are always liable to damage. If possible the lighting units are arranged round the perimeter leaving the central parking area clear. The vitreous enamelled angle reflector is often suitable, but where the park is large wide-angle floodlights with a rapid run back of the type described earlier are effective.

Almost all the usual light sources have been employed, including colour-corrected mercury discharge lamps and tubular fluorescent lamps which, in decorative lanterns, can provide a particularly attractive installation.

**(4.8) Industrial Storage Areas**

Storage areas of factories, particularly iron and steel works, are often lighted so that work can continue after dark. Fig. 21 shows the yard of Colvilles Ltd., Motherwell. The light source is the 1-kw. mercury vapour lamp mounted at 45 ft. with, in addition, two localised lights under the crane gantry.

Another example is a coal storage area at a London gasworks (Fig. 22). The area is lit by 12 floodlights on 80-ft. structures which are part of the coal-handling plant. This is one of the largest coal-storage areas in the country.

**(4.9) Lighting for Defence**

In contrast to every other lighting application, the lighting of a defended area is required to produce glare. The area will be surrounded by a perimeter fence behind which a guard is watching for unauthorised movement outside. It is desirable to produce as much glare as possible to persons approaching from outside, leaving the guard in darkness. One method is to use a comparatively small number of narrow-

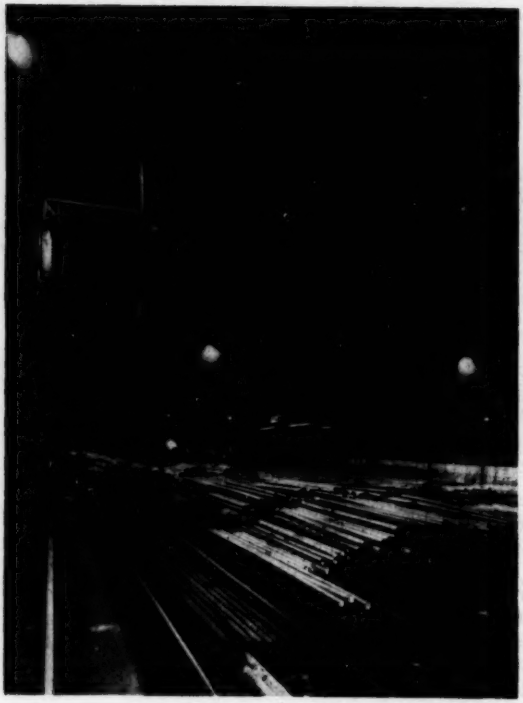
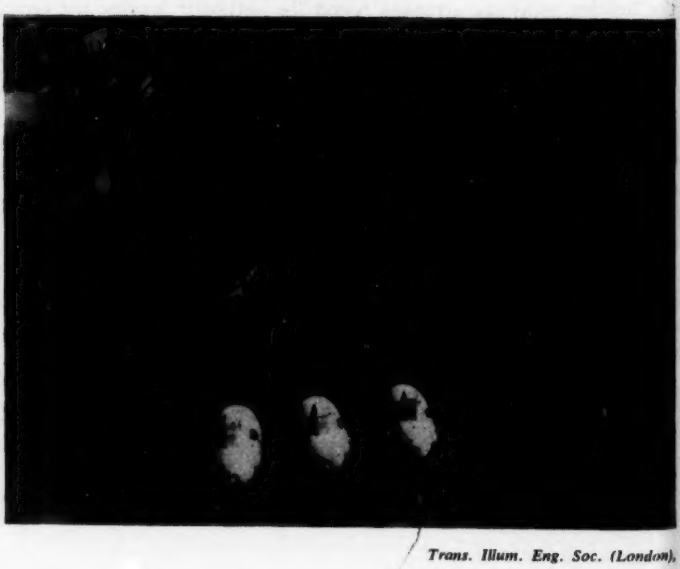


*Fig. 21. Steelworks yard lighting at Messrs. Colvilles, using 1kw. MB/V lamps.*

*Fig. 22. Coal storage area at gasworks lit by 1,500-watt floodlights on 80-ft. towers.*



beam searchlights sweeping the surrounding areas. This method is not favoured because it is possible for an attacker to watch the movements of the beam and either take cover or remain quite still when the beam is on him. It is far better for the glare and the lighting to be continuous all round the area.

Wide-angle floodlights giving a fan-shaped beam can be used, regularly spaced and mounted on the perimeter fence itself. This arrangement is somewhat uneconomical in the number of floodlights and also has the disadvantage that the floodlights are rather too accessible to malicious damage.

The boundary fence is frequently of an open wire mesh, and a good method is to mount floodlights in pairs on poles about 12 ft. high at a distance of about 20 ft. inside the fence: the beams are spread horizontally to illuminate the fence and the area beyond. The wire mesh of the fence should have a black finish so that it will not dazzle the defenders or make them visible by reflected light.

### (4.10) Open-cast Mining and Quarrying

Siting of units should make the best use of the terrain. As a rule, because the workings go in one direction, positions can usually be found from which the working face and the grabs can be illuminated. New positions may have to be found when the area of work is changed. Equipment which has to be moved frequently should, of course, be fairly light but must also be robust. Vitreous enamelled reflectors are often used. In floodlights, aluminium reflectors are lighter and less liable to damage than glass and are, therefore, preferred. Filament lamps are generally chosen to avoid the need for housing control gear with discharge lamps. Some portable equipment may well be useful, probably consisting of strong tripod stands carrying medium-beam floodlights. Such equipment requires trailing cables, however, and it is better to use more permanent positions with overhead wiring.

An illumination of 0.5 to 1.0 lm/ft$^2$ should be provided on the working face, and it is useful if some lighting equipment is sited near the loading points to provide a higher local illumination.

### (4.11) Civil Engineering Works

Some vast engineering projects, such as laying pipe lines across a desert and building intermediate pumping stations, have involved the provision of what amounts to a small portable town, including street lighting, defence lighting and lighting for the actual works. Equipment should be light in weight and operate reasonably satisfactorily even when damaged (as it certainly will be). It should be inexpensive, so that it can be replaced from stores if necessary, and it should be designed so that it can be easily packed for transport. Often, light distribution and luminous efficiency seem relatively unimportant and the main requirement is for simple and robust reflectors.

As a contrast, a lighting installation for dam construction will probably require accurately designed and focused floodlights, which will be fixed permanently in position until the building is completed. A dam is built across a valley and positions for banks of floodlights are found at each end of the area and above the level of the top of the dam.

With narrow beam floodlights considerable distances can be spanned and in the example illustrated, Fig. 23, the Wemmershoek Dam, South Africa, the opposing banks of floodlights are more than half a mile apart. The finished level of the wall is to be 180 ft. and the floodlights are 200 ft. above the bottom of the valley. In each bank there are 30 floodlights, 10 of which have 1,500-watt G.L.S. lamps, the remainder having Class B2 projector lamps: an average illumination of 3 lm/ft$^2$ is obtained on the working face.

*Fig. 23. Lighting for dam construction at Wemmershoek, South Africa.*

## (5) Some Aspects of Predicting Illumination in Installations

### (5.1) Accuracy of Calculations

Although the flux method mentioned in Section (4.1) is simple, it gives only the average value of the illumination over the whole installation. In the hands of an experienced engineer, with prior knowledge of the likely diversity, such information is often all that is needed, but where actual values of illumination at particular points in the installation are required they must be calculated by point to point methods. This requires a light distribution curve for the unit and repeated application of one or other of the well known formulae based on the inverse square law.

It should be realised that for any particular installation the calculated illumination may well be 10 to 20 per cent. different from that found in practice. The photometric data available for the fittings are usually average results for a number of samples and are based on mean-through-life light-output data for the particular lamp type. Variation in performance occurs between fittings nominally the same, particularly so with floodlights because of the critical nature of the optical system and the way it is focused. In practice, then, any one unit is unlikely to reproduce exactly the performance quoted on the average light distribution curve. Measurements in the laboratory on smooth beam fittings and floodlights may be reproduced to within about 5 per cent. using lamps of known light output, accurate voltage control and careful focusing. With peaky distributions variations of 10 per cent. or more are common. Hence, it is not unusual to find that illumination measurements on an actual installation differ from the calculated values by as much as 20 per cent. In installations where many fittings contribute to the illumination individual variations between fittings tend to cancel and measurements accord more nearly with calculation.

### (5.2) Method of Calculation

With many installations the fittings positions are determined by physical factors, an appropriate type of fitting is chosen and likely aiming directions selected. Calculations are then made to find the illumination reaching various points in the complete installation, but if the illumination distribution is not satisfactory new aiming directions

or different fittings have to be selected and the values recalculated. In this way the required distribution is obtained by successive approximations, although previous experience of similar installations can reduce the labour appreciably.

Most calculations to find the illumination at a point involve finding angles, such as the direction of the point from the fitting relative to some axis and the offset angles of the point from where the fitting light distribution is aimed. These offset angles are needed to obtain the intensity directed towards the point.

The work entailed in finding the angles is much reduced by using a commercially available slide rule[13] or by a graphical method due to M. W. Peirce, which is described in the Appendix.

Having obtained the angles and the corresponding intensities, the illumination value at the point may be calculated from formulae or more simply by using a second slide rule[14].

Where there are a number of fittings lighting an area calculations may be made for each individual fitting and the results summed. Often, particularly with floodlighting installations on towers, a group of fittings is close enough together and far enough away from a point in the installation to be treated as one fitting with a composite light distribution. Only a single calculation is then needed to find the illumination at a point when the intensities given by each individual fitting towards that point have been found and summed. If other towers contribute, similar calculations can be made for each and the total illumination found.

The labour involved in planning installations is considerable and many short-cut methods have been devised to lighten it. Where only one type of fitting is involved, comprehensive data for it may be computed and the results combined into graphical, tabular or model forms so that installations may be planned more quickly. In common with so many design problems, the effectiveness of such methods depends on the skill and ingenuity of the particular designer.

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# Appendix

## Graphical Method for Finding Angles in Illumination Calculations

The principle of the graphical method is illustrated in diagram Fig. 24(a). A lighting fitting L is mounted above the horizontal surface ABCD, and it is required to find the angles involved in calculating the illumination at any point X on this surface. The angle in azimuth relative to AB, $\widehat{ABX}$, is given directly from the angle scale on

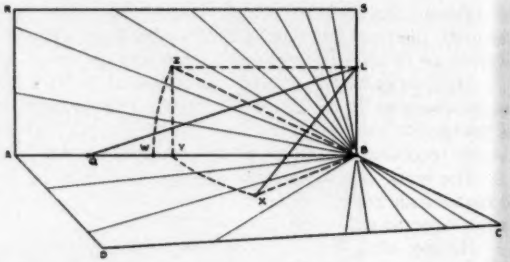


*Fig. 24a. Principle of graphical angle calculator.*

ABCD. The angle of elevation of XL, $\widehat{XLB}$, is found by drawing an arc with centre B and radius XB to meet AB at Y, and drawing a vertical line to Z equal in length to the mounting height LB. Because LB is equal to ZY and BX to BY the angle YZB is equal to $\widehat{XLB}$ and may be read from the angle scale on ARSB.

These angles in azimuth and elevation are respectively the angles of longitude and latitude defining the direction LX on an isocandle diagram for the fitting drawn with the axis of symmetry of the light distribution vertical. The intensity in direction LX can then be found and the illumination at X calculated.

If the axis of symmetry of the light distribution for the fitting is not directed vertically towards B but to some other point Q, say, along BA as would be the case with a floodlight mounted at L and directed towards Q, then the angle needed to find the intensity directed towards X is the true angle QLX and the procedure for finding it is given later.

The actual diagram used in practice is shown in Fig. 24(b), derived by folding outwards plane ARSB of Fig. 24(a) so that it lies in the same plane as ABCD. Scales for mounting height and plan distance are then added and the diagram used as follows.

A plan of the area to be lighted is drawn and the fitting positions marked on it. A diagram similar to Fig. 24(b) is drawn to the same scale on tracing paper and placed

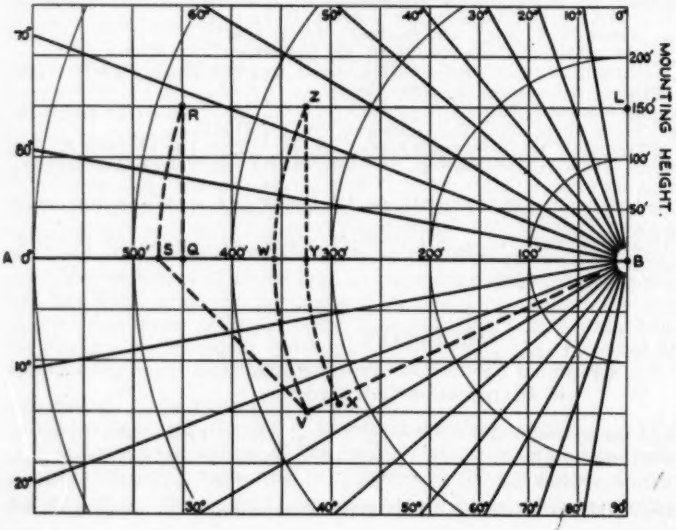


*Fig. 24b. Graphical angle calculator.*

over the plan with the point B on one of the fitting positions. The line BA is placed on the line from the fitting position to the aiming point of the fitting. Taking the lower half of the diagram, the angle in azimuth on the horizontal plane between the aiming point and the point for which the calculation is to be made can be interpolated, e.g., at point X it is 26 deg. The angle of elevation for point X is determined as described for Fig. 24(a) and is 66 deg.

A little consideration will show that on this diagram other angles and distances are easily found by drawing appropriate triangles or transferring lengths by means of arcs of circles on to the distance scales. For example, LX, the slope distance of the fitting to the point is found by drawing an arc centre B, radius BZ to meet the distance scale along BA and reading off the required length at W. In the example illustrated it is 360 ft. Similarly the slope distance to the aiming point Q can be found by drawing an arc from R to meet the distance scale BA at S, where RQ is equal to LB the mounting height of the fitting.

From the light distribution data of a symmetrical floodlight, the intensity in the direction X when the axis of the beam is directed towards Q can be obtained if the true angle QLX is known. This angle is found as follows :—

Continue the arc ZW to a point V such that the distance SV=QX on the plan. The angle SBV (in this case 25 deg.) is the angle QLX we require and can be read on the angle scale. This is so because BS equals the slope distance LQ, BV equals the slope distance LX and SV, the third side of the triangle, is equal to the true distance QX.

Along the axis line AB the angle QLY or any other similar angle can be obtained more simply by reading on the upper angle scale the angles represented by R and Z and subtracting (since RBZ=QLY). In this case the angle QLY=72 deg.−66 deg.= 6 deg.

On the diagram the line BA is taken as a horizontal reference line. If the area to be lighted is not level the effective mounting height of the fitting will vary for different points on the ground and due allowance can be made on the diagram.

## Discussion

MR. A. R. McGIBBON: A very wide range of subjects has been covered, of some of which I have no first-hand experience, but I would like to say a few words in regard to transport lighting.

The authors have divided railway yards up into three groups, but I think in practice they could be divided into four.

Firstly, the Marshalling Yard in which wagons are sorted and made up into trains. Whilst the standard of illumination mentioned in the paper of 0.5 lm/ft$^2$ to 1 lm/ft$^2$ is desirable, quite good lighting is obtained in practice with illumination values of not less than 0.5 lm/ft$^2$ in the working area and 0.15 lm/ft$^2$ for walking purposes. In the walking area beyond the points, which forms the main portion of the yard, the staff have to use hand lamps for label reading, note taking, and coupling up wagons. The labels are situated on the sole beam of the wagon which is shadowed by the overhanging portion, so that the general yard lighting cannot penetrate here, and it is also rarely possible for the coupling chain and hook to be seen without a hand lamp.

Secondly, there is the Goods Yard, where loading and unloading of merchandise takes place, and here at least 1 lm/ft$^2$ is required, with good penetration of light into the covered wagons or road vans. Floodlighting from high towers is not suitable for such work.

Thirdly, there are what is known on the railway as Private Sidings, i.e., sidings serving coal mines, gas and electricity, and other large works. These sidings are

essentially for the storage of wagons, and, provided there is lighting at the inlet and outlet ends similar to that installed for marshalling yards, there is usually little need to light the storage area except for supervisory purposes.

Fourthly, there are Carriage Sidings, where carriages are serviced and a minimum of 1 lm/ft$^2$ on the platforms between the roads is desirable, but vertical illumination is the important thing here.

The authors have dealt quite fully with the question of floodlighting for various purposes, for many of which this method of lighting appears to be the only satisfactory solution, but for railway use floodlighting has certain advantages and disadvantages. Some of the advantages can be summarised as follows :—

It reduces the number of obstructions causes by poles.

The diversity of illumination is lower than when local lighting is used.

It provides good overall lighting particularly between wagon roads for walking purposes.

The floodlights are situated above the smoke line and therefore tend to keep cleaner than do those at a lower mounting height.

It gives a good general visibility over the yard as a whole, which is useful for supervision.

It reduces the number of points to be maintained.

Some of the disadvantages, however, are :—

The size of the base of the tower, about 16-18 ft. square for a 150-ft. tower, plus clearance to wagon. It is not always easy to find space in the best position in a yard for such a base.

The vertical illumination on the sides of wagons is not always good, which is important where staff have to see the brake handles.

For reasons already mentioned, hand lamps cannot always be dispensed with.

Due to the long travel of the light beam the absorption of light is greater in fog than when lower mounted lights are used, and, in addition, the beacon effect is lost so that in fog the shunters tend to lose a sense of position.

There is a further point to be considered, which has nothing to do with illumination, but the loss of light from one tower due to mechanical or electrical failure would be very serious to the working of a yard at night and would probably cause complete stoppage until it was restored.

Finally I would like to endorse what the authors said about the design of floodlights which can be re-lamped and cleaned without loss of adjustment. The correct training and focusing of floodlights is quite a long business, and it is essential that the electrician should not disturb this setting during maintenance.

In conclusion I would like to thank the authors for the valuable collection of data contained in the paper and for the method of determining the angles as described in the Appendix.

MR. M. GAUGHAN: At one of our high tower installations in the North of England, we obtained some information on the effect of fog. In this installation 150-ft. towers were mounted 1,500 ft. apart and illumination readings were taken on a clear night, and also on a foggy night. The description of the fog was that a main-road street lantern, mounted at 25 ft., was invisible from the base of the next column, and under these conditions the illumination mid-way between the towers had only fallen to 50 per cent. of the clear-night value. It appears from this that the fog hazard to high tower lighting is not necessarily as great as was expected, although it may be that the particular fog was low lying.

MR. J. M. WALDRAM: The authors have indicated some quite refined methods

of calculation of illumination from projectors, and some of the installations which have been illustrated demonstrate that the uniformity achieved may be quite important. This implies that the variability of performance of the projectors and of their components, and the variations likely to occur during servicing, are as important as the original photometric data and the calculations made. The whole question of floodlight design, the means whereby tolerances are applied and allowed for in the equipment and its components, and the means of aiming, and if need be re-aiming, are involved. The comments of the authors on these points would be particularly welcome.

They mentioned the Infranor projector, which is, I believe, of Swiss origin. In addition to the feature of an adjustable mirror, whereby the beam shape can be set to match approximately the shape of the target, this projector has another feature which was not mentioned: it has also a backing mirror, usually in the form of a silvered bulb lamp, which cuts off all uncontrolled bare lamp light, so that only the main beam emerges. I believe that the striking results which have been achieved by this projector are quite largely due to this feature, rather than to the adjustable beam. The beam flux from the projector is not very high, for the mirror is shallow and has a small pick-up. There is surely nothing which one 3-kw. Infranor projector can do, so far as the illumination of the target is concerned, which could not be done equally well by two or three 1-kw. conventional projectors located close together; indeed, installations such as that at Buckingham Palace, 25 years ago, demonstrated that excellent directional effects were possible with large banks of projectors of conventional form quite close to the target, provided that they were appropriately orientated. What is important is not what is lighted, but what is not lighted; and the facility for restricting the light strictly to certain regions without spill is very important. The spill light lights the surroundings to the target and the foreground to the projectors, increasing the adaptation level, offsetting the lighted effect, and increasing the haze.

On the point raised by Mr. Gaughan, I am sure that his explanation is correct—that the layer of fog on that occasion was limited to little more than 25 ft., so that the light from the street lighting was wholly within it, whereas only a small part of the optical path of the light from the floodlights was in the fog. This is a condition which may well occur in radiation fog conditions, and might well have the results which he quotes. But it would be most unwise to infer from them that fog is of little moment. If the fog bank were only a little thicker, the light from the floodlights would be attenuated catastrophically, for the attenuation function is logarithmic. Both fog and smoke layers (which attentuate with little scatter) can occur at all sorts of heights and thicknesses, independently of each other, and the interference which they cause in air traffic, when the pilot has only to see the lights as beacons not having to illuminate anything by them, is sufficient evidence of their importance.

MR. A. G. PENNY: I would like to continue the discussion regarding tolerances in the optical system raised by Mr. Waldram.

The equipment used in the various types of open-space lighting described by the authors is not of the high-precision type. The lamps are usually ordinary general service types with screw caps pressed out of thin brass and inserted into unpretentious holders of similar metal; the fittings are frequently constructed of sheet metal with reflectors of spun metal or blown glass.

While it may be possible for an expert properly to adjust the equipment when it is first installed, any subsequent handling, as for instance the replacement of a lamp, must inevitably entirely destroy the original adjustment.

Nevertheless, there are in existence very many installations of this kind which have been in use for a long time and given satisfaction. One is driven to ask whether the careful planning and precision of installation stressed by the authors is really necessary.

Having said this I must confess that, with Mr. Waldram, I also have a feeling that the success of the Infranor is in part at least due to the fact that the use of fewer, but higher-powered, units makes the problem of maintenance easier. I would also suggest that the dramatic effect so often associated with Infranor installations may also be due to the use of high-power units placed at a few strategic points. Powerful beams of light illuminated by atmospheric haze play an important role in creating the overall effect.

MR. J. G. HOLMES: Several speakers have referred to the Infranor projector, and I recall an aerodrome floodlight of somewhat similar optical design which was employed at Croydon, Gatwick, Heston and elsewhere before the war. The floodlight comprised a 1,500-watt lamp on the focus of a "para-barrel" mirror consisting of six segments each about 2 ft. square and individually adjustable so as to project a horizontal fan of light, which could be adjusted to suit the contours of the landing area. The optical efficiency was high, and the results were excellent, but the floodlight was extremely difficult to focus, and in the passage of time it gave place to the parabolic cylinder mirror and a line filament lamp up to 2,000 watts, which proved to be much more powerful and reliable.

In the discussion on the mounting height of floodlights, no reference has been made to the economic aspects. Increased mounting height would call for higher accuracy of the floodlights and would involve greater losses due to atmospheric absorption, so that apart from the cost of the towers there would probably be a most economic height for any particular open space. The comments of the authors on this matter would be of considerable interest.

The photometric efficiency of the floodlight is also a matter of economics, because a precise optical system giving an accurate and consistent distribution of light together with a high beam factor will always be more acceptable than a less precise article. I noticed that the authors and several speakers referred to football-ground floodlighting systems in terms of the total wattage provided, and it seems that this would favour the less precise and less efficient floodlight if it were adopted as a matter of specification.

MR. C. DYKES BROWN: Reference is made in the paper to football league matches being played on grounds where the lighting load is between 200 and 300 kw. This is small compared with the loading at some of the well-known stadia in America, where higher levels of illumination are obviously necessary to follow the small ball used in baseball matches. Nevertheless, it would be interesting if the authors could tell us whether the loading now used in this country for lighting football grounds is comparable with that in other parts of the world, and also whether they anticipate any further increase of loading in this country in the future.

MR. R. H. SANDERS: The authors state that on oil wharves and jetties flameproof 500-watt and 1,000-watt floodlights are generally employed. I would appreciate further clarification on this point as I was under the impression that because of the temperature limits imposed by BS 889 (flameproof electric-light fittings) it was not practicable to produce floodlights for this lamp size and wattage, particularly in the case of the 1,000-watt lamp. In general I would say that these installations are more often lit by means of flameproof pendant fittings up to 300-watt tungsten filament lamp size, or alternatively, by means of 80-watt fluorescent flameproof units.

MR. A. H. NASH: Little mention has been made of space lighting with electric discharge lamps and the only installation illustrated used vertically burning 1-kw. MB/V Lamps. Controlled distribution for this type of application is important, as confirmed by the authors' useful contribution on this aspect. The authors' comments

would, therefore, be valued on the comparison between vertically and horizontally operated mercury discharge-lamp equipment for particular applications.

MR. D. J. REED: I have seen in a recent copy of the transactions of the American IES an article on the xenon lamp. This article included photographs of projectors mounted on the Empire State Building. I should like to ask Mr. Stephenson whether he thinks there is any immediate possibility of this source being applied to area lighting in this country.

MR. D. C. PRITCHARD: There are some rather loose statements regarding illumination levels for outdoor lighting. An example to-night was the figure quoted for railway yard lighting. The authors quote values of 3 lm/ft$^2$, whereas Mr. McGibbon, from his personal experience, quoted values below 1 lm/ft$^2$. The main point of my remark is that calculations based on these gentlemen's recommended values show a variation in installation costs of 300 per cent. A very good example experienced by the lighting engineer is that of car park lighting. Here again, published figures quoted vary from ½ to 3 lm/ft$^2$, all supposedly capable of providing sufficient illumination. Is it possible for some code to be provided covering illumination values for outside lighting?

MR. A. GREENAWAY-BROWN: The authors have referred to "Defence Lighting" without giving any definition of the meaning of these words. As I believe this is the first time that this subject has been mentioned at any meetings of this Society, I should like to be informed of where and for what purpose "Defence Lighting" is required.

MR. G. K. LAMBERT (written contribution): I have been impressed most by the pictorial survey of different types of installation. The authors would have a large number of installations to choose from but many would have to be discarded for lack of suitable photographs. Photographs to illustrate fairly and accurately the appearance of an installation are extremely difficult to obtain.

It is not to be expected that in such a wide survey the authors could say much on installation design methods. The method demonstrated in the paper emphasises the labour and the complexity of the task. Except in a few cases it is most unsafe to rely on total area and an estimate of effective lumens. The "spherical chart" method demonstrated at the Society's Summer Meeting at Harrogate in 1956 consists of plotting the area to be lit on a chart, on which beam coverage does not vary with the angle of tilt of the projector; planning can be carried out with the aid of a simple "beam coverage" templet. This is comparatively simple and has the attraction for the engineer that he can "see" what he is doing at all stages of the design, particularly in choosing the most suitable projector and in deciding how much of a given area can be covered from a particular tower.

MR. G. ROBERTS (written contribution): A high-elevation lighting scheme has been in service in the British Railways' Southern Region at Hither Green Marshalling Yard since September, 1955, and all its claims appear to have been justified.

The yard is 1,900 ft. long by 400 ft. wide, and is lit by two 150-ft. towers with 32 1,000-watt floodlights, 14 on one tower and 18 on the other, 27 of these units being fitted with spreader glasses, the remainder with plain glasses.

The average illumination over the yard is 0.2 lm/ft$^2$, with a diversity of 6 : 1.

Taking up the points made by the speakers, the use of high-elevation lighting in fog and mist does not create any special problems, since with mist the light is diffused, and without much loss, whilst conditions of thick fog, which would prevent adequate lighting, would be such that low-level lighting would also be rendered ineffective.

The maintenance of the units is simplified by the use of a pre-set device which

enables the fitting to be swung away from the working position, and returned with positive location. This device has proved very satisfactory in service.

Reduction in maintenance work is achieved with high-level lighting by its concentrated groups of units as against the large numbers of individual fittings with attendant cable, posts, etc.

With reference to the discussion on railway wagons, it is not quite clear what type of wagon was being considered by the speaker. It is agreed, however, that the lighting of the open-type wagon presents no difficulty from high-level sources. Regarding closed vans, it is appreciated that it is impossible to illuminate the whole of the interior, and that hand lamps must still be used.

The yard staff has confirmed its complete approval, and in its view the system will reduce both accidents to personnel and derailments. It is also suggested that in event of a derailment, there would not be the complementary damage to lighting poles, fittings and wirings caused by the use of mobile cranes.

This form of lighting engenders a feeling of confidence in the staff, and work generally is speeded up. It would appear that these facts are largely due to the lowering of the diversity factor, consequent reduction of glare, and lessening of the necessity of the eye to adapt itself to varying levels of illumination.

THE AUTHORS (in reply): We are indebted to Mr. McGibbon and Mr. Roberts, from whose special experience of railway yard lighting much useful data has been added to the paper. There is little that needs comment, and it is encouraging to note that the high tower scheme at Hither Green is successful and liked by those who work under it. We agree on the necessity for localised lighting at loading bays, and for the limited use of hand lamps inside closed wagons.

The effect of mist and fog has been mentioned by several speakers. In our view its effect on space lighting installations, particularly the high-mounted types, is often exaggerated, and the comments of Mr. Gaughan and Mr. Roberts are welcomed. As indicated in the paper, misty conditions may even improve an installation.

Although Mr. Waldram's remarks on attenuation are strictly correct we would suggest that the instance cited is not applicable because aircraft landing speeds are high, whereas in most space-lighting applications movement is relatively slow and the need to pick out objects immediately and with certainty not so vital. In addition, the site is usually familiar to the workers, and unless the fog is so dense that all activities have to cease, they can work surprisingly well with only partial visibility of familiar objects.

Another point worth recalling is that when using searchlights, target visibility is improved if the observer is offset from the searchlight so that he is not looking down the beam. This condition is approached with the higher mounting height installation.

The main reasons for the success of the Infranor projector have been well set out by Mr. Waldram, and we fully agree with his comments and those of Mr. Penny on the importance of what is not lit. As mentioned in the paper, the long focal length mirrors combined with compact low voltage high efficiency filaments allow narrow beams to be projected from a distance.

With regard to tolerances and means of allowing for them, the elaboration needed in the unit can be costly, and the customer is not usually prepared to add appreciably to the capital cost of an installation. Nevertheless, we would emphasise our comments in the paper that if pre-focus capped lamps were used more frequently many of the variables caused when re-lamping could be kept within acceptable tolerances. For example, in some re-lamping tests on a medium angle floodlight using a Class B2 filament lamp with G.E.S. cap, it was found that the beam axis was moved by as much as 3½ deg. in the horizontal and 2 deg. in the vertical when a new lamp

was inserted. This was an extreme instance among the dozen lamps tried; a more usual shift was about 1½ deg. The maximum shift could have been reduced to about 0.2 deg. with a pre-focus capped lamp. Proper mechanical design could ensure that the lampholder and optical components were carried on the same framework so that misalignment could not easily occur and the unit even be pre-focused at works. In addition, location devices on the horizontal and vertical movements of the trunnions, such as are fitted to the floodlight shown in Fig. 6, may be set during the initial training of the floodlight. If subsequently the unit is moved, it can be returned to the original training and elevation. With regard to Mr. Penny's comment on past installations with fittings not having these features, it should be remembered that in a well-designed scheme any point will receive contributions from several floodlights, so that the effect of failure or misalignment of any one will be minimised. The larger the installation the less likely is the overall effect to deteriorate on servicing.

Mr. Holmes has raised the question of economics for high mounting installations. It is not possible to generalise, and as we were careful to emphasise in the paper each scheme has to be considered in relation to local circumstances. Economics are by no means the major deciding factor, and the quality of the lighting needed for the particular application, freedom from glare, ease of maintenance and neatness of the installation are but a few of the items to be considered. For the likely range of mounting heights and target distances, floodlights are available with appropriate beam intensities and divergences, and in practice the best mounting height is unlikely to be decided by the characteristics of the floodlight.

With regard to the use of total wattage for specifying football field lighting, we agree that neither it nor illumination values by themselves can be accepted as suitable yardsticks for measuring seeing conditions. It is not a simple matter to specify a method for taking illumination measurements on football grounds, since so many surfaces in different planes are important, and in our view illumination should not be used. Since pitches are of similar size and well designed floodlights of similar efficiency, we would suggest that the method proposed by the Football Association is reasonable. This specifies the minimum angles from points on the pitch to the floodlights, minimum total wattages for different sizes of ground, that light is substantially confined to the playing area (which determines the optics of the units) and recommends that the installation be planned, trained and focused by specialist lighting engineers.

In reply to Mr. Dykes Brown, loadings used in the best installations in this country are comparable to those in other parts of the world. We do not know of any association football stadium with more than 400 kw. One of the most recent installations in Germany has a loading of 384 kw. and for comparison our own Chelsea ground is 400 kw. In the U.S.A. higher loadings are used on baseball grounds, but these are about double the area, the ball is much smaller in size and the spectators further away so that a higher illumination is needed.

With loadings of 300-400 kw. for the larger grounds, a well-designed installation gives excellent visibility and we do not think there is anything to be gained by increasing the lighting load as such.

Proper consideration is not always given to engineering the installation. Such matters as the light distribution, positioning and aiming of the lights need most careful design in order to provide good seeing conditions for both players and spectators. If these factors are not properly understood an increase of power may well lead to poorer results rather than an improvement.

We agree with Mr. Sanders on the usual methods of lighting oil wharves and jetties. As mentioned in the paper, floodlights are used when it is necessary to light from a distance, although large certified floodlights equipped with 500- and 1,000-watt lamps are available and have been in service for many years.

In reply to Mr. Nash, we showed illustrations of installations using fittings equipped

with both horizontal and vertical-burning H.P.M.V. lamps. Where a well-controlled light distribution in the vertical plane is needed the horizontally operated lamp is preferable, and Fig. 16 illustrates its use. For general lighting at short throws the vertical-burning lamp is generally used, but the high efficiency and luminance of the 1-kw. MB/V lamp makes it very attractive for area lighting at the intermediate throws, and because of its comparatively short arc length a controlled light distribution can be achieved.

Mr. Reed has inquired whether xenon lamps are likely to be used in this country for area lighting. In its present stage of development the lamp is best suited for use in optical systems such as film projectors where its small source size, high luminance and excellent colour can be utilised. The life is about 500 hours, starting and operating gear are complex, the efficiency is only about 30 lumens per watt, and the lamp is costly.

For some specific applications where one of its properties, such as good colour, is important, it might be useful, but we do not think the lamp will be much used for area lighting until the life is comparable to that of other sources and the cost is reduced.

We agree with Mr. Pritchard that it might be useful to have a code giving recommendations for outdoor lighting. The preparation of such a code, however, would not be easy. Suitable illumination levels depend on the surroundings to any particular installation and need to take into account the greater diversity usual in out-door installations as compared with lighting in interiors. In addition, the success of many space-lighting schemes lies as much in the siting of units as in providing a given average illumination level.

Some recommended values of illumination will be found in the I.E.S. Lighting Handbook, Second Edition (U.S.A.) and in *Illuminating Engineering*, **52**, 118 (1957).

In the example of railway-yard lighting quoted in the paper and mentioned by Mr. Pritchard, the value of 3 lm/ft$^2$ was in the vicinity of the points, the average was about 1 lm/ft$^2$, and at mid-span about $\frac{1}{2}$ lm/ft$^2$, This illustrates not only the importance of correct siting of towers to obtain higher illuminations over special areas, but also how difficult it might be to codify the problem by unique illumination values. Perhaps a code giving lumens over an area, as used in the street lighting code, might provide a more satisfactory working basis.

The definition and purpose of defence lighting was requested by Mr. Greenaway-Brown. Defence or protective lighting is used for night-time policing of military or industrial properties. It may be used in the sense described in the paper to detect unauthorised approach to an area by lighting outwards from the perimeter fence, and at the same time because of glare to stop those outside observing activities inside. It is also used to illuminate storage areas as a deterrent to pilfering.

Installation design methods have been referred to by Mr. Lambert. His "spherical chart" technique is ingenious, and it would be of interest if a fuller description could be published and some indication given of the cost of making the hollow spherical model needed.

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# Diploma in Lighting Engineering

Under the revised constitution of the Society (adopted at an extraordinary general meeting held on March 26, 1957) the former Register of Lighting Engineers is discontinued and in its place a special class of member known as Diploma Member is created.

The Council may elect as a Diploma Member anyone who holds the Society's Diploma in Lighting Engineering or whose name is included on the Society's Register of Lighting Engineers at the time of election (Art. 5 (iv)).

Members whose names were included on the Register of Lighting Engineers have been notified of these changes and given an opportunity of transferring to the new class of Diploma Member.

Regulations governing the award of the Society's Diploma in Lighting Engineering have been approved by the Council and will come into force on October 1, 1957. Forms of application for the Diploma and for Diploma Membership may be obtained from the Secretary.

## Regulations Governing the Award of the Society's Diploma in Lighting Engineering

1. A Corporate Member of the Society who fulfils the conditions given in Regulations 2, 3 and 4 below, or whose name is included in the Society's Register of Lighting Engineers on October 1, 1957, may, on approval by the Council, be awarded the Society's Diploma in Lighting Engineering.

2. A Corporate Member applying for the Society's Diploma must comply at the date of application with the following conditions :—
   (i) be at least 25 years of age ; and
   (ii) have been a member in some class for not less than three years (By-law 7); and
   (iii) have passed a Final examination in Illuminating Engineering of the City and Guilds of London Institute or have obtained an equivalent qualification approved by the Council ; and
   (iv) give satisfactory evidence of knowledge of ancillary subjects (see Regulation 3) ; and
   (v) prove to the satisfaction of the Council that he has been engaged in lighting practice for a period of not less than five years and has shown competency therein (see Regulation 4).

3. Applicants are required to show knowledge of ancillary subjects to the following standard :—
   (i) Electrical engineering to the standard of the Ordinary National Certificate in Electrical Engineering ; or
   (ii) Physics to the standard of the Ordinary National Certificate in Applied Physics ; or
   (iii) Architecture to the standard of the Intermediate Examination of the Royal Institute of British Architects ; or
   (iv) The Engineering Institutions' Examination (Part I) ; or
   (v) Any equivalent examination approved by the Council.

4. (i) An application must be supported by three referees who must be members of the Society and who are able and willing to confirm some or all of the statements made in the application. At least one of the referees shall be from outside the organisation with which the applicant is employed.

(ii) An applicant may be required to produce a certificate, signed by a responsible person who has personal knowledge of the facts stated, that he has been engaged in lighting practice for not less than five years. This period may, at the discretion of the Council, be reduced to three years for applicants who have already attained a recognised standard in an allied field.

(iii) An applicant may be required to submit to a test to satisfy the Council that he is capable of applying the principles of good lighting and is familiar with Codes of Practice and regulations in regard to lighting.

(iv) If an applicant bases his application on experience in one particular field of lighting he will be required to show specialised and detailed knowledge of that field as well as a general knowledge of the fundamentals of lighting.

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## Annual General Meeting

The annual general meeting of the Illuminating Engineering Society was held at the Royal Society of Arts, John Adam Street, London, W.C.1, at 5.30 p.m. on Tuesday, May 14, 1957. The President, Dr. W. E. Harper, was in the chair. The Secretary read the notice convening the meeting and the statement of the auditors for the year ended December 31, 1956.

In presenting the report of the Council and the accounts for the year the President said that the report was in a rather different style from previous reports, attention this time being directed to the considerable work done by committees. Membership had fallen by 39 during the year. The Membership sub-committee of the General Purposes Committee was proceeding with a long-term plan for increasing membership and a new brochure on the Society was in the course of preparation. Centres were being invited to appoint their own membership development committees, and in due course all members would be invited to participate.

Liaison between individual Centres and between Centres and headquarters continued to be achieved not only by the representation of Centres on Council but by meetings of the Centres Joint Committee. The President and Vice-Presidents had visited most of the Centres and some of the Groups during the year. The appreciation of Council of the work done by the chairmen, honorary secretaries and committee members of Centres and Groups was recorded in the report.

As had been anticipated expenditure had exceeded income during the year. Steps had been taken however to raise the rates of annual subscriptions at an extraordinary general meeting held in May, 1956, and the new rates had come into operation on January 1, 1957.

During the year the Council had considered a revised constitution for the Society which had been submitted at an extraordinary general meeting in March, 1957, and had been approved by members. The revised constitution amongst other things permitted the creation of a new class of Diploma Member which had been introduced to meet objections which had been made to the present Register of Lighting Engineers.

Dealing with new developments not covered by the year under review the President mentioned that as from January, 1958, the Transactions of the Society would be improved in format. A new Technical Committee had been appointed and plans were now being made for the celebration of the Society's Golden Jubilee in 1959.

Mr. R. R. Holmes pointed out that in the accounts the amount received as annual renewal fees from Registered Lighting Engineers was not shown as a separate item, and he asked how much money had been received in this way and how it had been used. The Hon. Treasurer in giving the amount said that the money had been included in the general income and pointed out that with the adoption of the revised constitution this annual charge would be discontinued though the annual subscription of those

included in the new class of Diploma Member would be increased by a similar amount.

The adoption of the report and accounts was proposed by Mr. D. W. Durrant, who also proposed a vote of thanks to the President, officers and members of Council for their conduct of the Society's affairs during the year. This was seconded by Mr. R. Pelerin. The report and accounts were declared approved.

Dealing with the election of officers and members of Council for the 1957-58 session, the President said that no other nominations having been received the following were declared elected:—

*President:* Mr. E. B. Sawyer.

*Vice-Presidents:* Mr. F. X. Algar, Mr. N. Boydell, Dr. R. G. Hopkinson, Mr. J. S. McCulloch, Mr. C. C. Smith.

*Hon. Treasurer:* Mr. W. Robinson.

*Hon. Secretary:* Mr. J. G. Holmes.

*Hon. Editor of the Transactions:* Mr. H. Hewitt.

*Members of Council:* Mr. A. E. Bird, Mr. C. Dykes Brown, Mr. J. B. Collins, Mr. P. H. Collins, Mr. A. E. Gaster, Mr. A. G. Penny, Mr. W. Imrie Smith, Mr. A. Wilcock.

After the remuneration of the auditors for the current year had been agreed the meeting was declared closed.

## Additions to the List of Members

The following applicants have been duly elected by the Council to membership in the Society and their names have been added to the list of membership:—

SUSTAINING MEMBER:—

Stretford Corporation.....*Representative*: H. Johnston.
Town Hall, Stretford.

CORPORATE MEMBERS:—

| | |
|---|---|
| Black, W. A. ..... | 128, Bishops Mansions, Bishops Park Road, LONDON, S.W.6. |
| Coldrick, F. A. ..... | 79, Uplands Avenue, Bradmore, WOLVERHAMPTON. |
| Copeland, E. C. ..... | 26, Crossway, Bush Hill Park, Enfield, MIDDLESEX. |
| Godfrey, Miss W. M. ... | 28, Avenue Rise, Bushey, HERTS. |
| Goldman, R. V. ..... | 15, Arkwright Road, Sanderstead, SURREY. |
| Hammond, R. J. ..... | 22, Wickwane Road, Beverley, EAST YORKS. |
| MacKenzie, A. G. ..... | 9, Hornsey Lane Gardens, Highgate, LONDON, N.6. |
| Meadowcroft, A. J. ..... | 8, Woodlands Avenue, Ribbleton, Preston, LANCS. |
| Mistry, B. R. ..... | P.O. Box 10264, Nairobi, KENYA COLONY. |
| St. Clair Mulley, H. S. ... | P.O. Box 8214, Causeway, Salisbury, SOUTHERN RHODESIA. |
| Neal, V. G. ..... | 6, Harley Road, Harrow, MIDDLESEX. |
| de Lisle Nichols, J. W. ... | Trinity House, LONDON, E.C.3. |
| Ozada, R. H. ..... | 12, Mufti Ziai Efendi, Nicosia, CYPRUS. |
| Poole, J. B. ..... | 31, Fareham Avenue, Rugby, WARWICKSHIRE. |
| Purdey, J. O. K. ..... | Marycourt, Englefield Green, SURREY. |
| Roberts, P. T. ..... | 132-135, Long Acre, LONDON, W.C.2. |
| Scott, K. ..... | 17, St. Peter's Road, LEICESTER. |
| Tucker, W. J. ..... | 11, West Hill Road, Cowes, I.O.W. |
| Weston, R. F. ..... | 1, Church Lane, Rearsby, LEICESTERSHIRE. |

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